Benefits of Improved IEQ: Better Health and Improved Work Performance

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Acknowledgments: M Mendell, O Seppanen, Q Lei, A Mirer, E. Eliseeva

Presentation Outline*

- Motivation
- Well documented impacts of IEQ on health and performance
- Benefits of example IEQ improvement scenarios
  - See paper for calculation methods
- Future research priorities

*This presentation incorporates some corrections in estimated benefits and costs relative to the estimates in the paper available in the conference proceedings

Motivation

Why quantify the health, productivity, and economic benefits of improved IEQ?

- Input for policy (e.g., ventilation standards)
- Guidance for building design & operation
- Research prioritization
- Awareness of importance of IEQ

Examples of Indoor Exposures with Well-Documented Impacts on Health, Comfort, and/or Performance

- Environmental tobacco smoke
- Ventilation rates (outdoor air supply)
- Temperatures
- Dampness and mold
- Air conditioning

Well documented:

Multiple quality studies with generally consistent findings

Best if statistical (meta) analyses have been performed of body of data

Environmental Tobacco Smoke Health Impacts

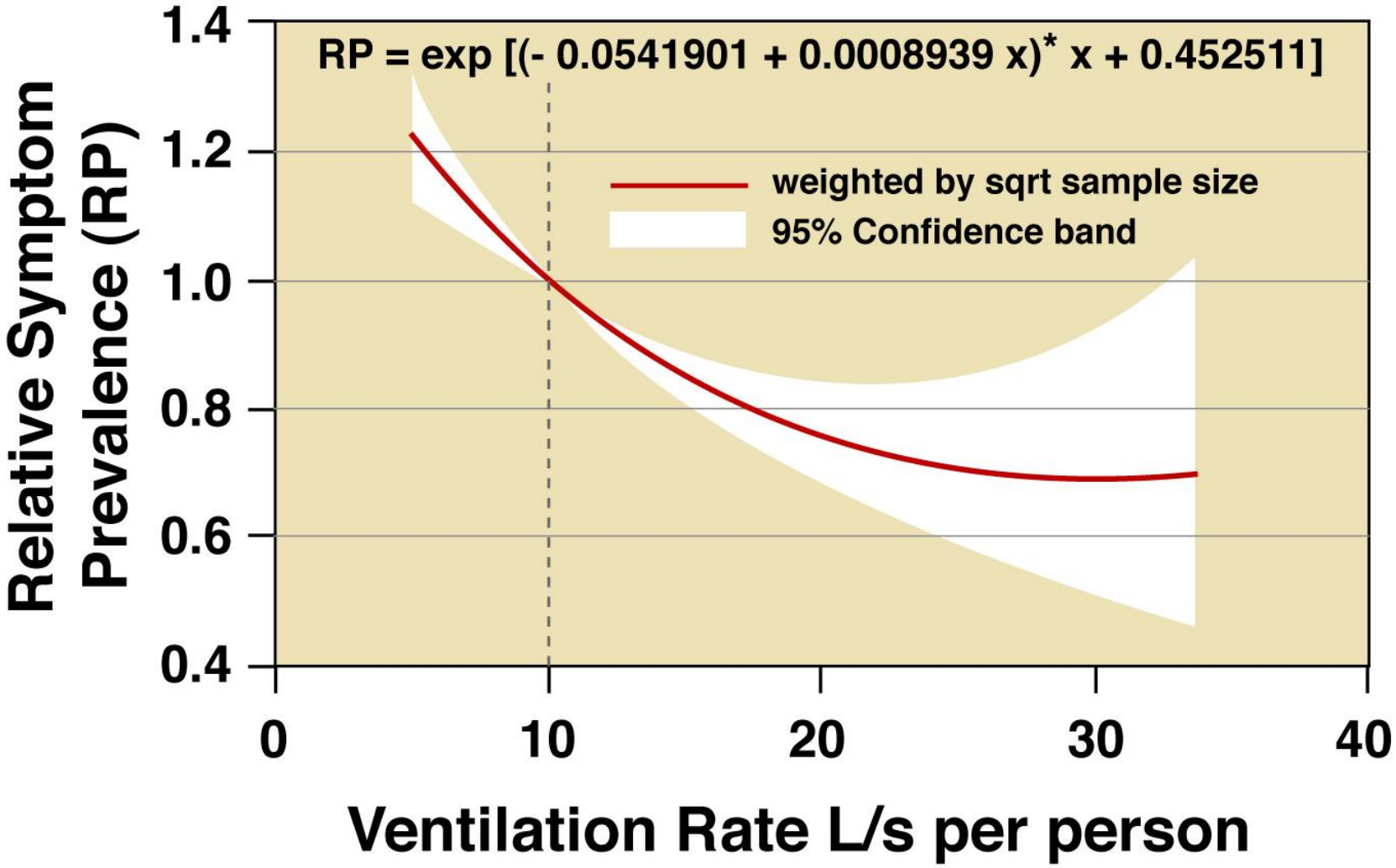
Analyses by California EPA

Health Effect	Estimated Annual ETS-Caused Cases in U.S.
Asthma exacerbations in children	200,000
Otitis media (ear infection) in children	790,000
Cardiac deaths	46,000
Lung cancer deaths	3,400
Low birth weight	24,500
Pre-term delivery	71,900

California Tobacco Control Program → decreased smoking in CA → estimated health care savings of $10 Billion per year as of 2004 (Lightwood et al 2008). California has 12% of U.S. population

Relationship of Ventilation Rates in Offices with Building Related Health Symptoms

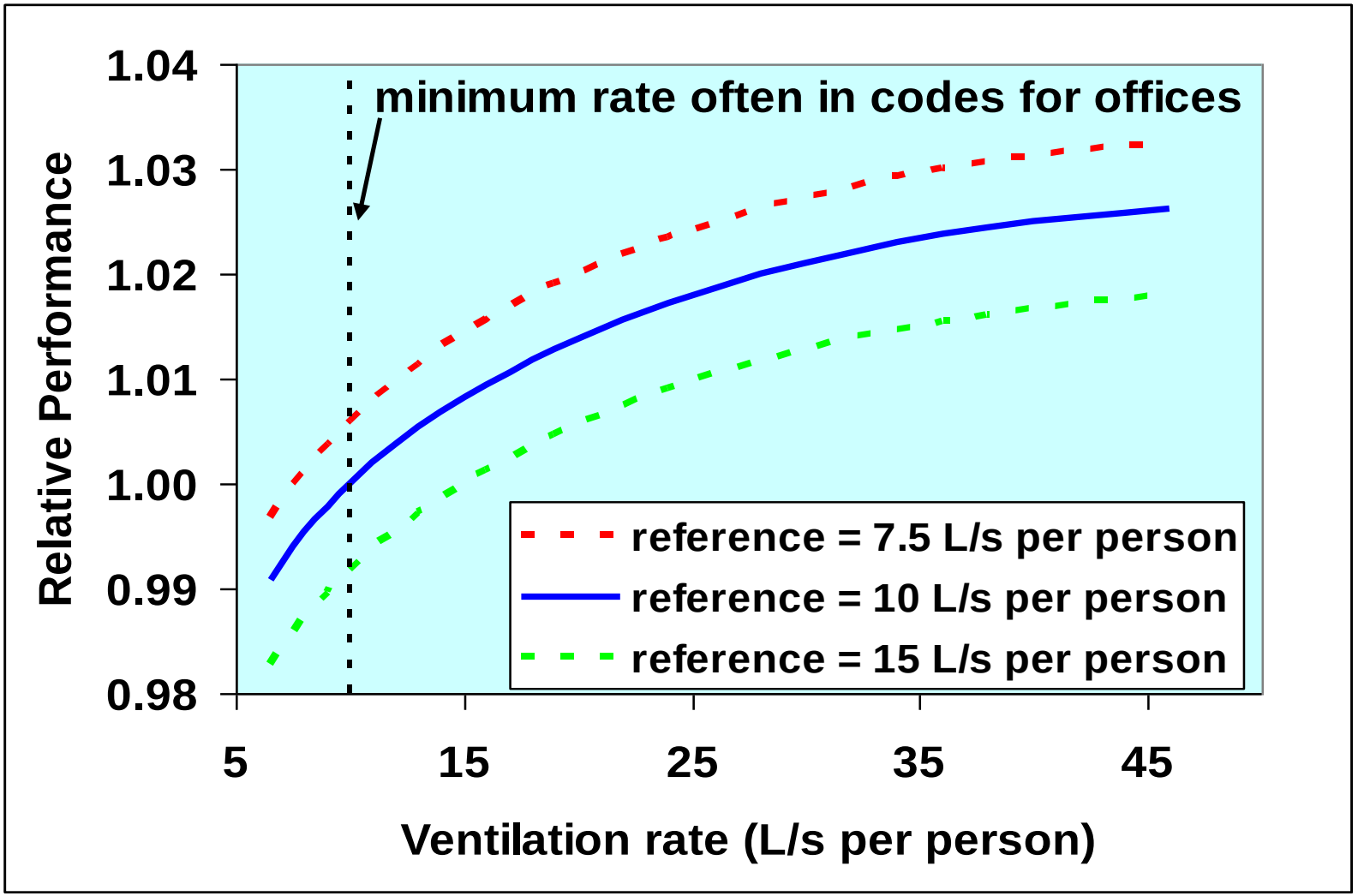
Statistical Analyses of 8 Studies with 43 data Points



Source: Fisk, Mirer, AG, Mendell, MJ (2009) Indoor Air 19(2): 159-165.

Ventilation Rates in Offices and Work Performance*

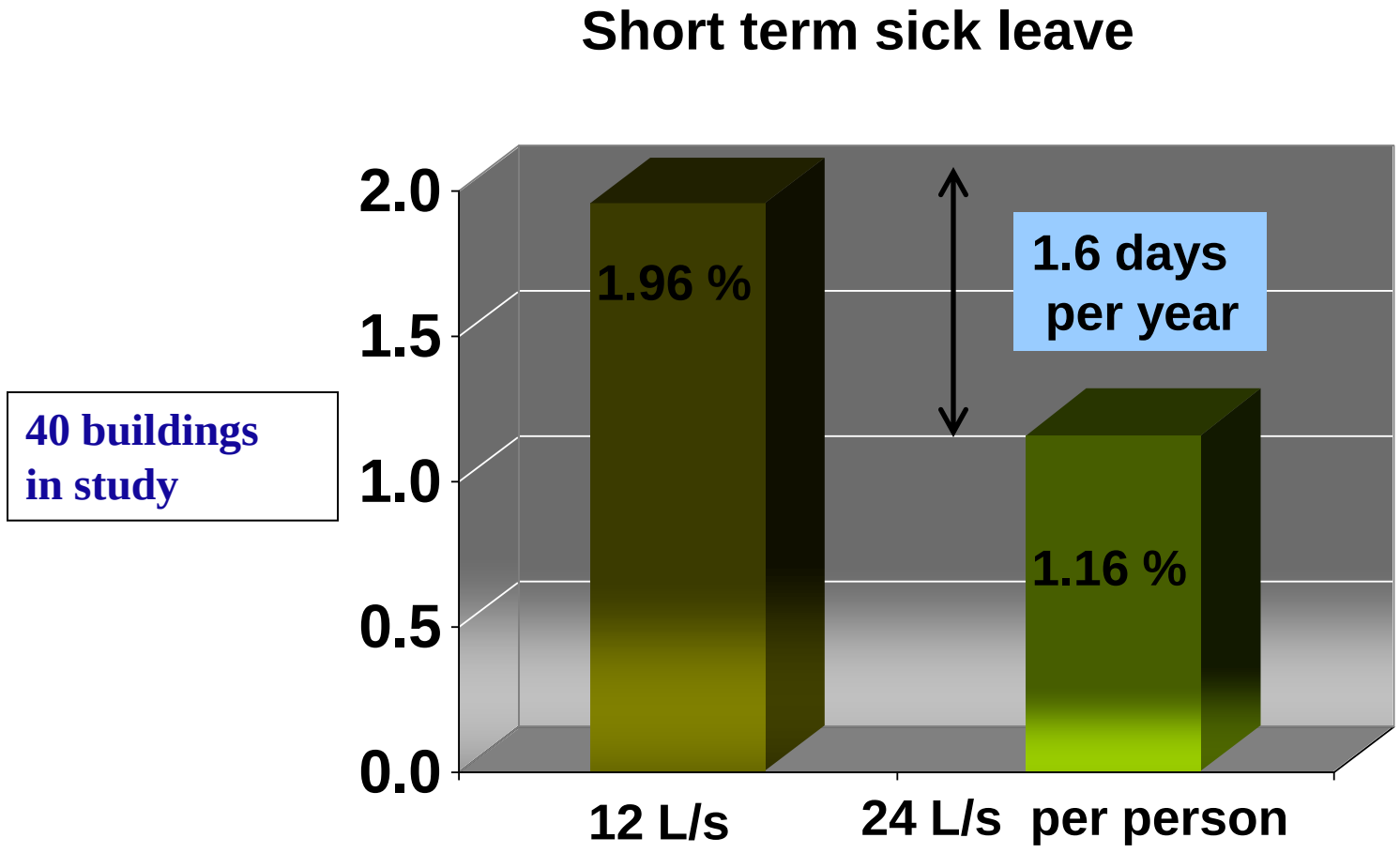
Results from Statistical Analyses of Nine Studies with 26 Data Points



*Speed of call center work & speed and accuracy of various tasks

Source: Seppanen O, Fisk WJ, Lei QH (2006) *Indoor Air* 16:28-36.

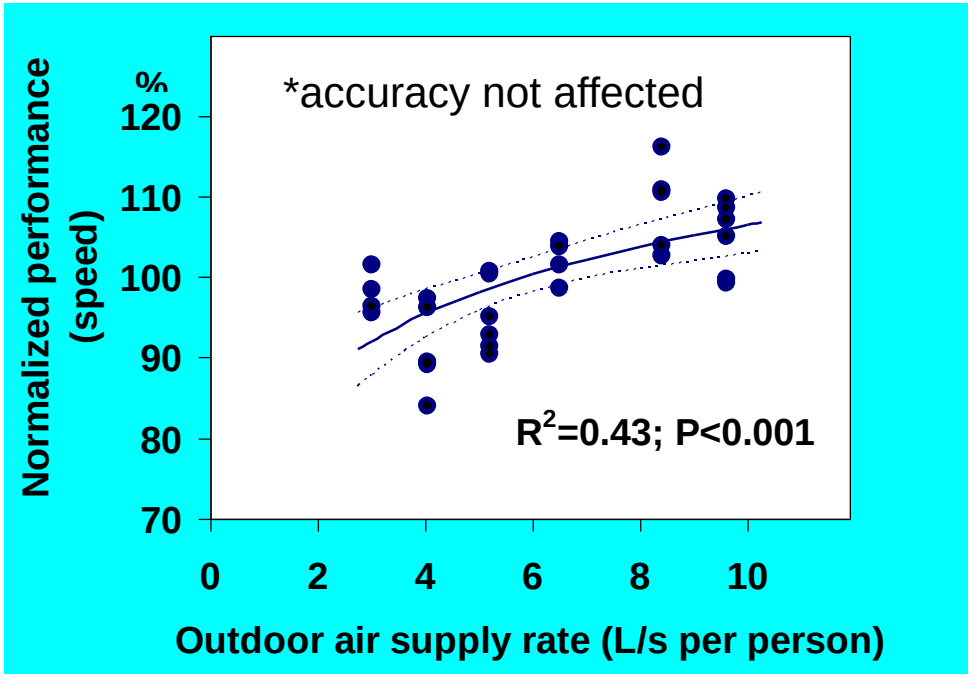
Ventilation Rates and Short Term Sick Leave in Offices

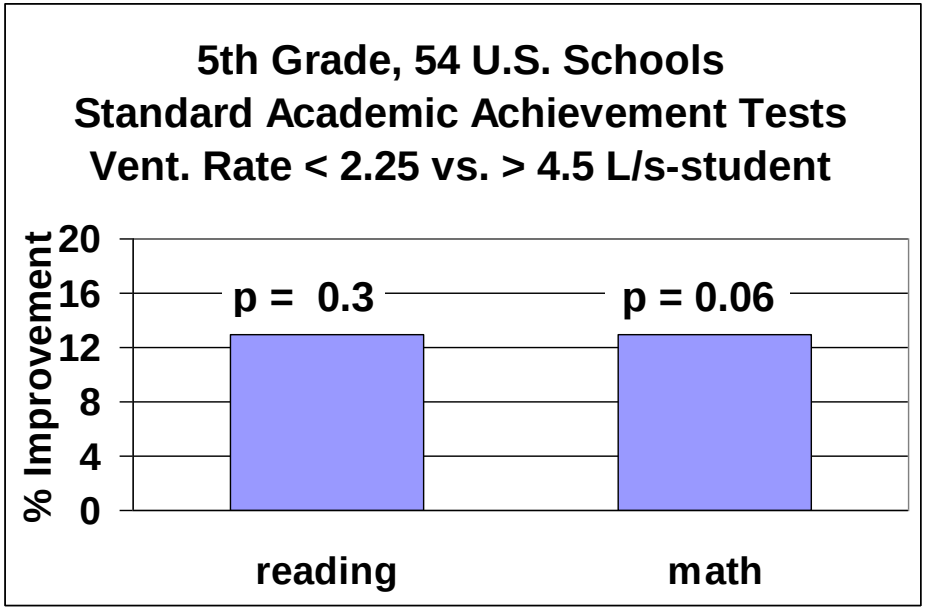


Source: Milton et al. (2000) Indoor Air Journal

Relationship of Ventilation Rates in Schools with Performance of School Work

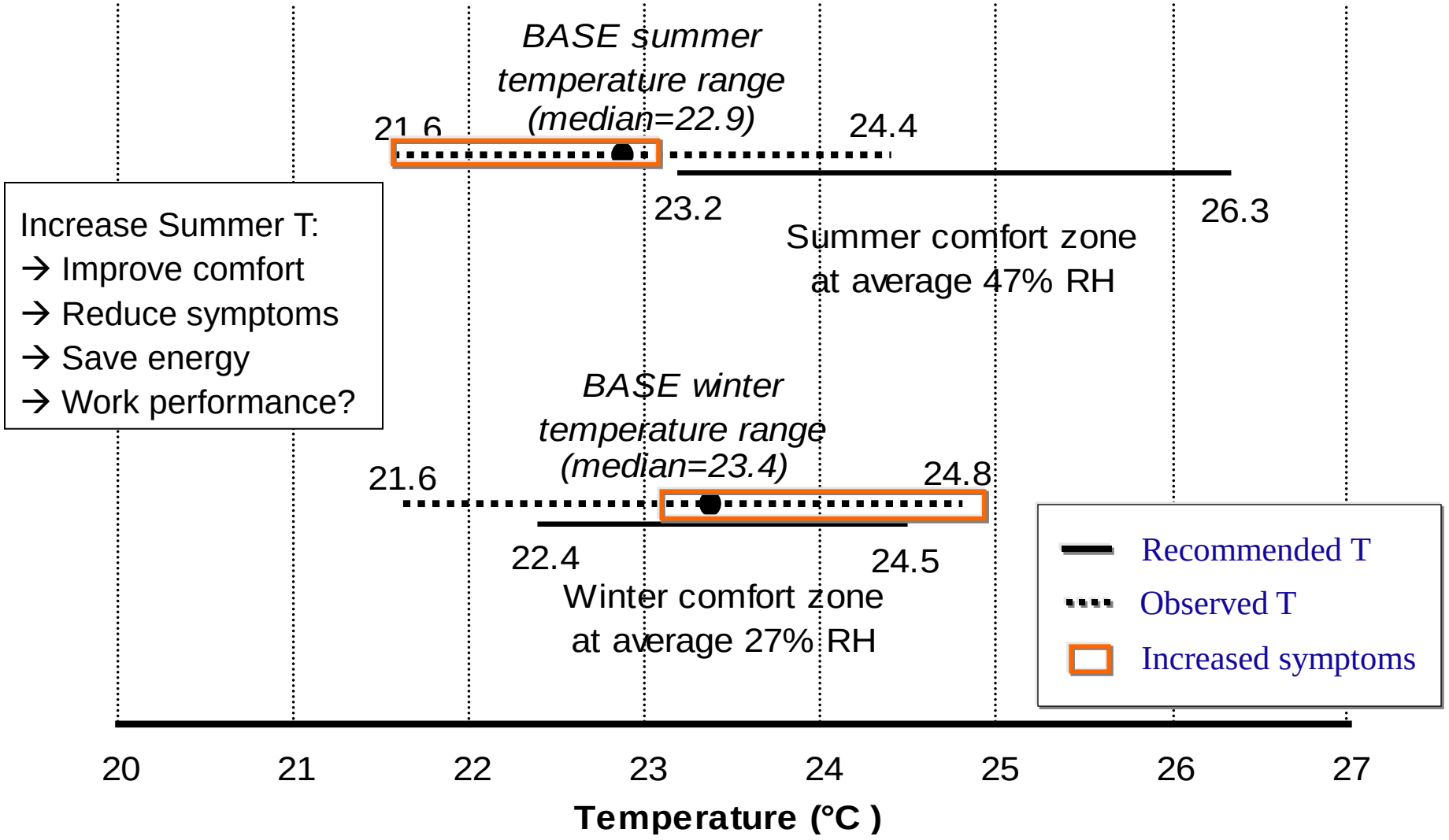
Experiments in 4 Danish Classrooms*





Sources:
Wargocki and Wyon *HVAC&R Research*, 2007. **13**(2): p. 193-220.
Shaughnessy, R.J., et al. Proc. Indoor Air 2005, *Indoor Air*, 2006. **16**(5): p. 465-468

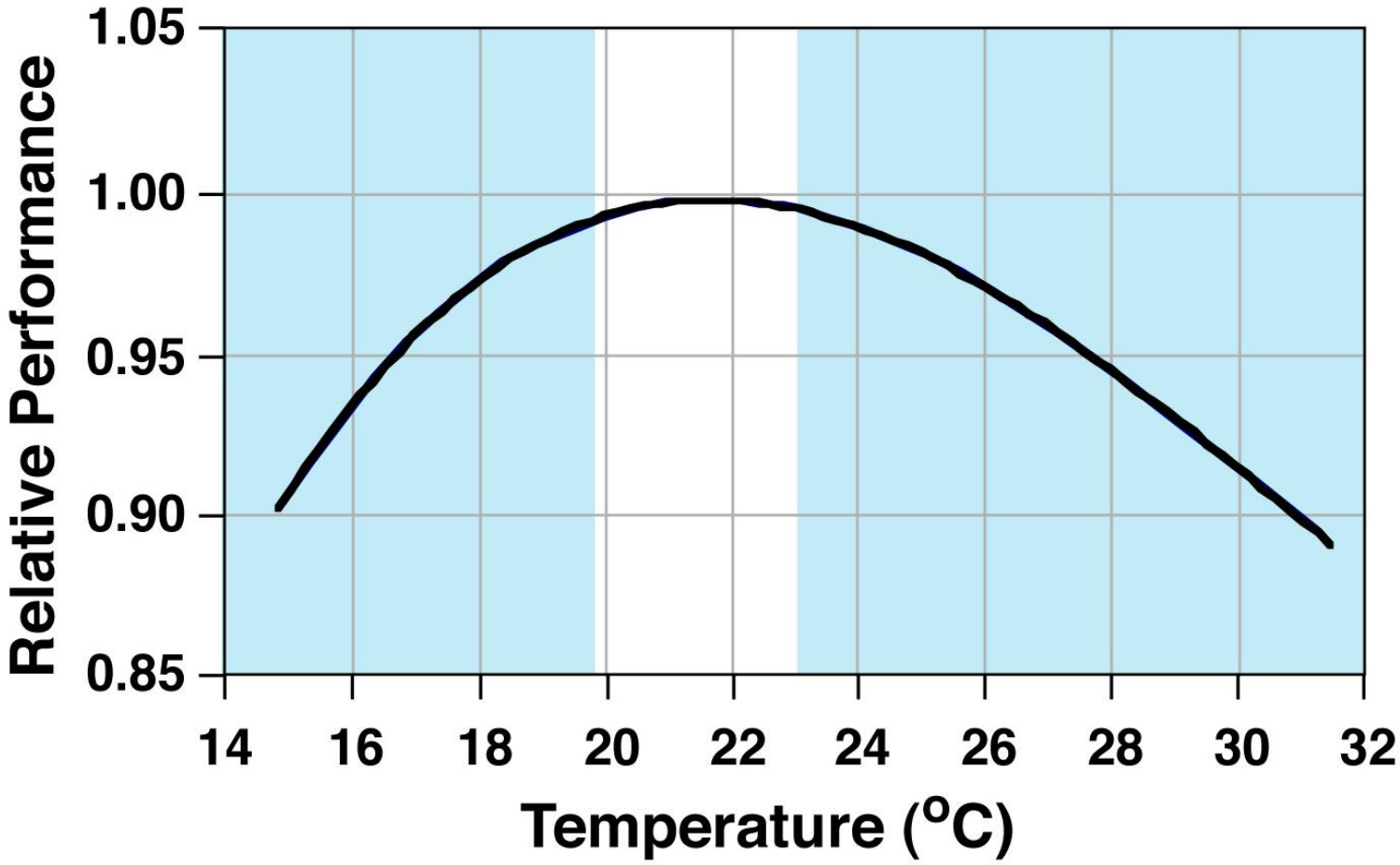
Observed vs. Recommended Temperatures in 100 U.S. Office Buildings & Relationship to Building Related Health Symptoms



Source: Mendell, MJ, Mirer. AG (2009) Indoor Air 19(4): 291 - 302

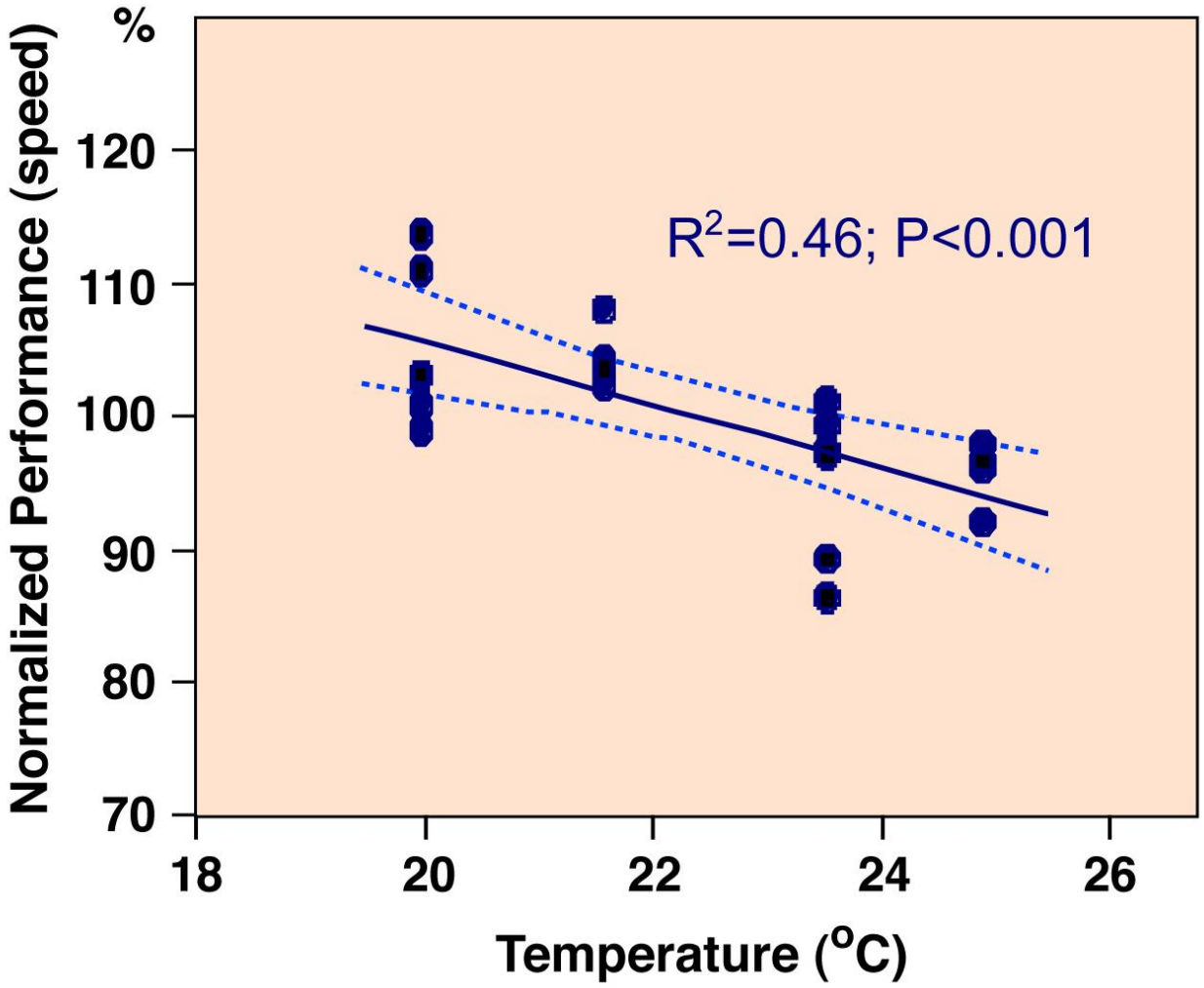
Temperature (or Thermal Comfort?) and Office Work Performance

From Statistical Meta Analyses of Results of 24 Studies



Source: Seppanen O and Fisk WJ (2006) *International Journal of HVAC&R Research 12(4): 957-973*.

Temperature and School Work Performance*

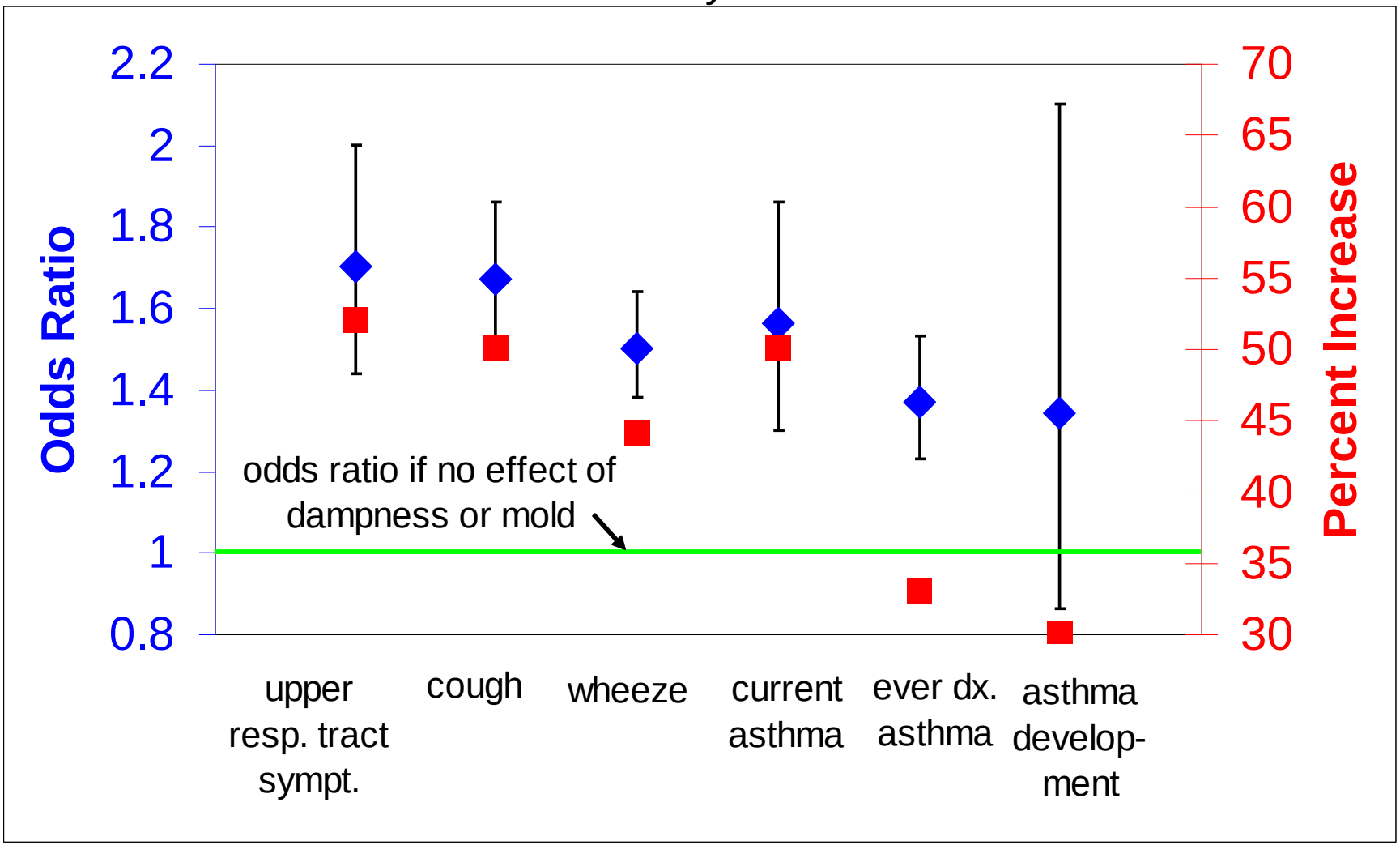


*accuracy not affected

Source: Wargocki and Wyon *HVAC&R Research*, 2007. **13**(2): p. 193-220.

Visible Dampness and Mold in Homes and Respiratory Health Effects

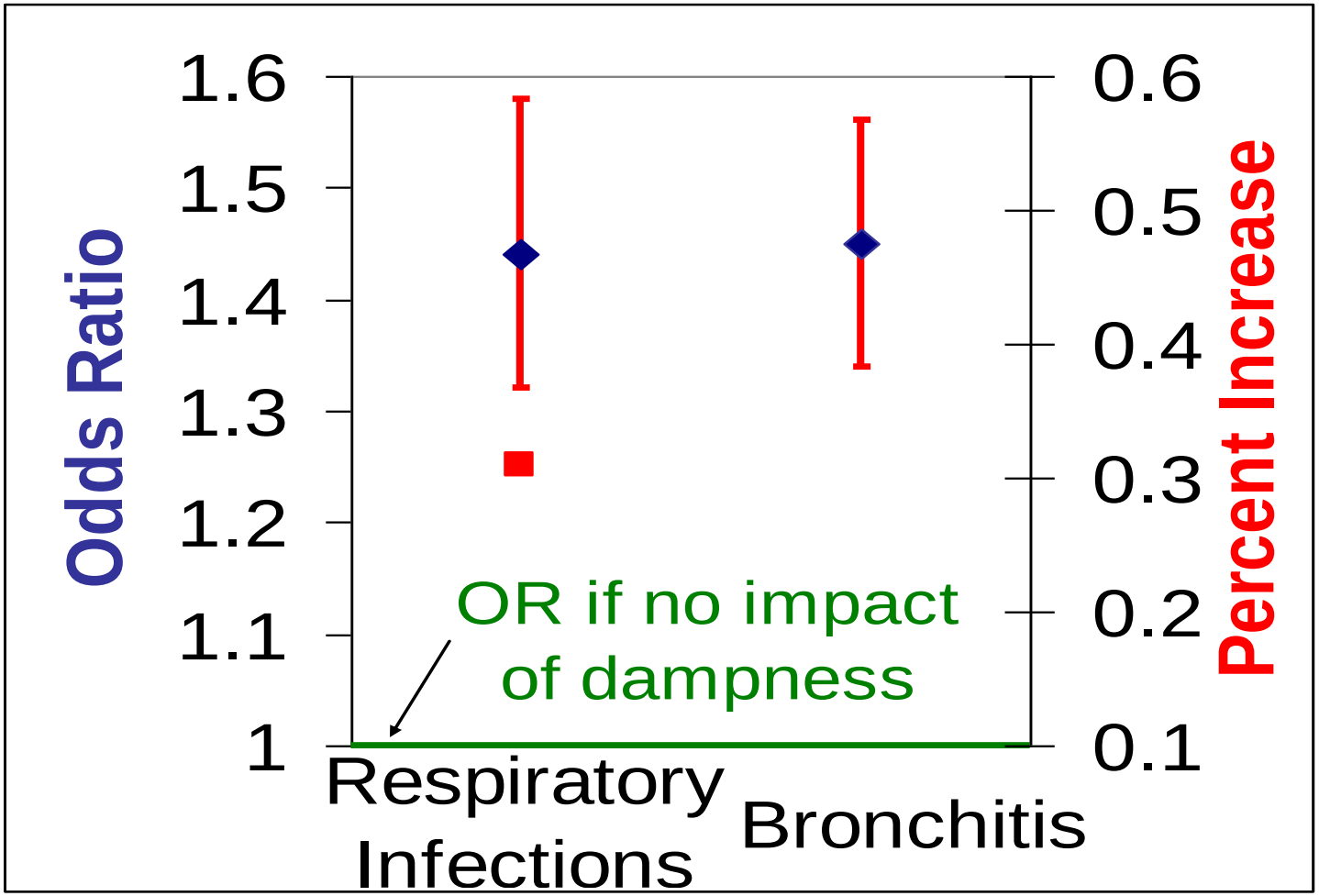
Results of Meta Analyses of 33 Studies



Source: Fisk, Lei-Gomez, and Mendell *Indoor Air*, 2007. **17**(4): p. 284-295.

Visible Dampness and Mold in Homes and Infections

Results of Meta Analyses of 23 Studies



Source: Fisk, Eliseeva, and Mendell *Submitted to Environmental Health*.

Air Conditioning (AC) in Offices and Increased SBS Symptoms

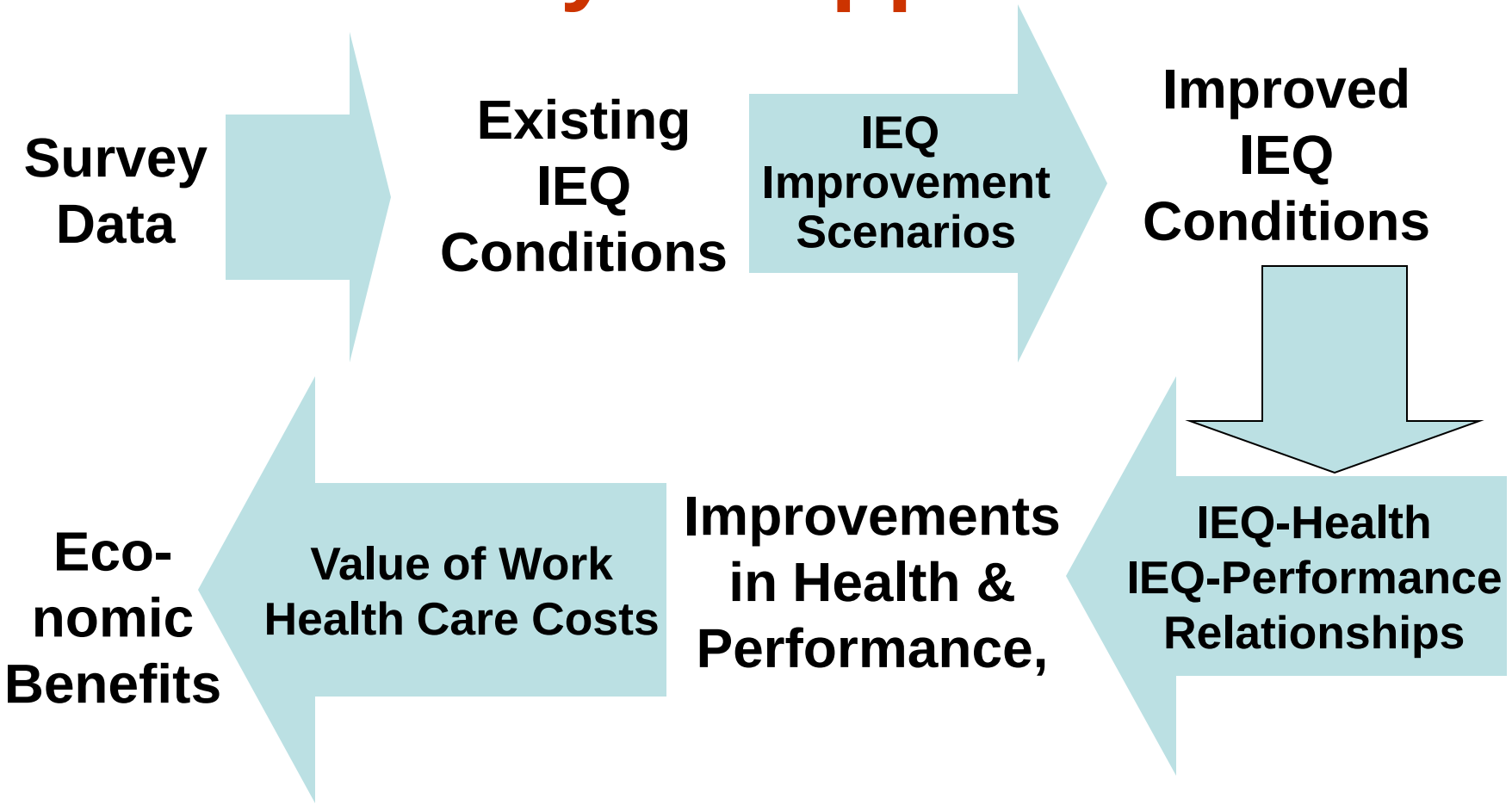
Type of ventilation system

First Author	Year	No of subjects	Natural Venti-lation	AC + No Humid.	AC + Steam Humid.	AC + Evap. Humid.	AC + Spray Humid.
Jaakkola	95	868	○	●			
Mendell	96	710	○	●			
Mendell, Burge	90, 87	1459	○	●			
Mendell, Harrison	90, 87	1044	○	●			
Zweers	92	2806	○	●			
Jaakkola	95	335	○	○	●		
Mendell, Burge	90, 87	863	○	○	●		
Zweers	92	3573	○	○	●		
Jaakkola	95	559	○	○	○	●	
Teeuw	94	927	○	○	○	●	
Mendell, Burge	90, 87	1991	○	○	○	●	●
Mendell, Finnegan	90, 87	787	○	○	○	●	●
Mendell, Harrison	90, 87	2080	○	○	○	●	●
Mendell, Hedge	90, 84	1214	○	○	○	●	●
Zweers	92	3846	○	○	○	○	●
Brasche	99		○	●	●	●	●
Hawkins	91	255	○	▥	▥	▥	▥

○ = Reference Group ● = Significantly more symptoms ▥ = Same #

Source: Seppanen O. and Fisk WJ (2002) Indoor Air 12(2): 98-112.

Benefits of Improved IEQ: Analysis Approach



Scenario 1

Increase Ventilation Rate in U.S. Offices to 15 L/s-person when Less

1.1 % Increase in Performance in 12 million workers ($10.2 billion)

Prevent Weekly SBS Symptoms in 0.6 million Workers ($0.1 billion)

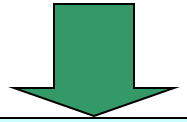
10 million Days Avoided Absence ($3.2 billion)

Increase Energy Use ($0.93 billion)

$12.6 Billion Annual Net Savings

Scenario 2

Add Outdoor Air Economizers to U.S. Offices when Absent

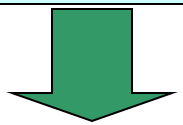


Avg. 0.5 % Increase in Performance in 21 million Workers ($7.2 billion)

Prevent Weekly SBS Symptoms in 1.6 million Workers ($0.3 billion)

15 million Days Avoided Sick Leave ($4.7 billion)

Decrease Energy Use ($0.12 billion)



$12.3 Billion Annual Total Savings

Scenario 3

Eliminate Winter Temperatures > 23 ºC in U.S. Offices

Avg. 0.2 % Increase in Winter Performance in 40 million Workers ($2.3 billion)

Prevent Winter Weekly SBS Symptoms in 7.7 million Workers ($1.1 billion)

Reduce Winter Thermal Comfort Dissatisfaction by 18% in 40 million Workers

Unquantified Energy Savings

$3.4 Billion Annual Total Savings

Scenario 4

Reduce Dampness and Mold in U.S. Offices by 30%

1.5 million Avoided Work-Loss Days ($0.5 billion)

Unquantified Avoided Remediation and Repair Costs

$0.5 Billion Annual Total Savings

Scenario 5

Reduce Dampness and Mold in U.S. Homes by 30%

1.5 million Avoided Cases of Current Asthma ($1.3 billion)

20 million Avoided Respiratory Infections ($2.0 Billion)

Unquantified Avoided Remediation and Repair Costs

$3.3 Billion Annual Total Savings

Scenarios 1 - 5

Work Performance Improved in 10s of Millions of Workers

Prevention of Weekly SBS Symptoms in Millions of Workers

Reduced Winter Thermal Comfort Dissatisfaction in 40 million Workers

1.5 million Avoided Cases of Current Asthma

20 million Avoided Respiratory Infections

Millions of Avoided Work Loss Days

Energy Costs of $0.8 billion plus unquantified energy savings

Approx. $30 Billion Annual Total Savings

Large Uncertainties Remain

- IEQ-health & IEQ-performance relations are uncertain
- Existing IEQ conditions not well characterized
- Interactions (synergies and overlaps) possible

Research Priorities

- How do ventilation rates in homes affect health?
- Is it air temperature or thermal comfort that affects work performance?
- What pollutant exposures explain the benefits of increased ventilation?
  - Source control and air cleaning options?
- How does IEQ affect performance of complex work?
- What are the mechanisms by which IEQ affects performance?
- Intervention studies to test and demonstrate the predicted benefits of improved IEQ.

For More Information

Read the paper in Proceedings

go to

www.iaqscience.lbl.gov